

Physics and Detector Study of New ILC Baseline Parameters

J. Brau

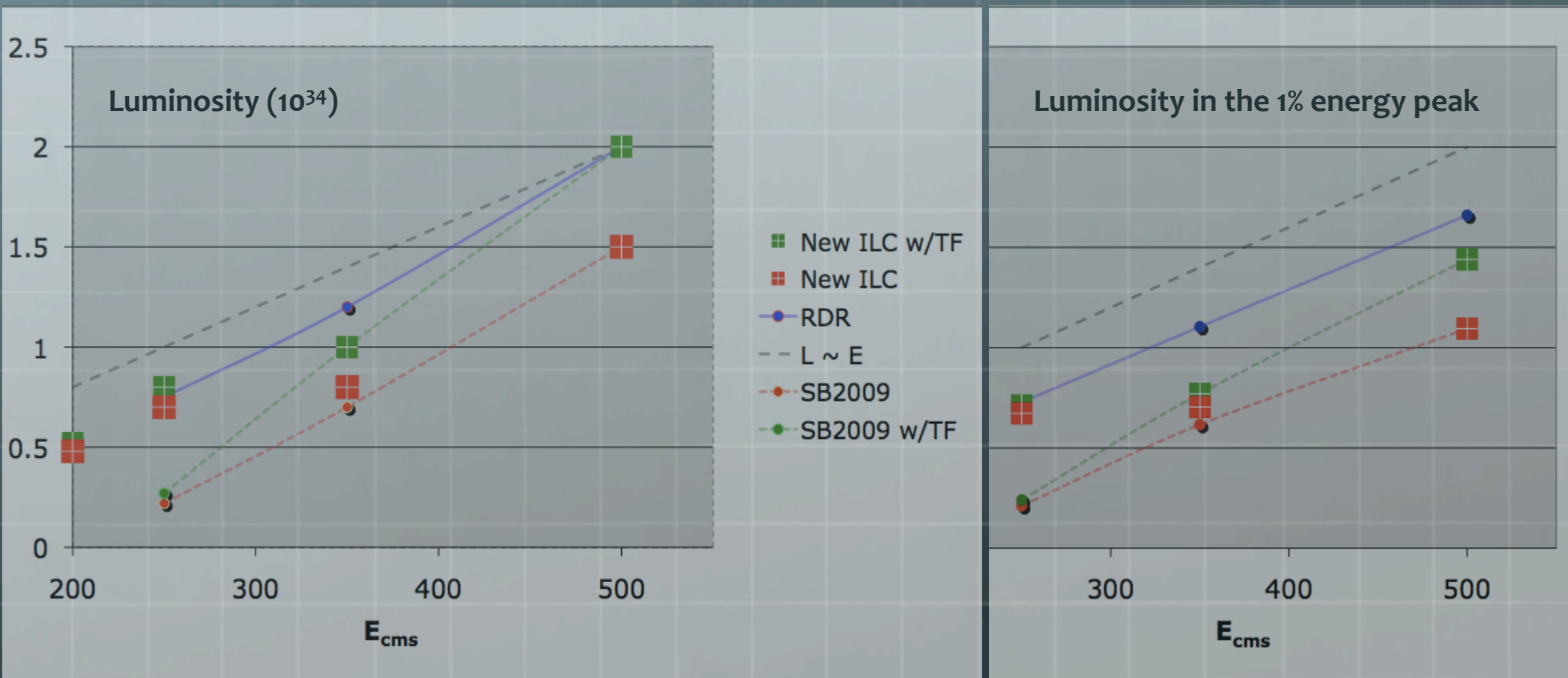
for the SB2009 Physics & Detector Working Group

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Miller,
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Physics and Detector Study of New ILC Baseline Parameters

- The Physics and Detector SB2009 Working Group studied the physics performance of the SB2009 parameters early in 2010.
- Physics performance degraded from RDR
 - Particular concern – reduced low energy luminosity
- These reactions led the GDE to revise the ILC design, with new machine parameters, which were developed before and after Beijing (LCWS2010 in March, 2010), and delivered to the physics community at the end of the summer, 2010.

ILC Machine Parameters









Topics Investigated

- Preliminary results of the NB studies were presented at the Eugene PAC meeting in November.
- The Working Group investigated the following aspects and physics processes:
 - Beamstrahlung losses
 - Machine backgrounds
 - Higgs mass, cross section, & branching ratios
 - Stau detection
 - Low mass SUSY scenario (an example)
 - Polarization
- The studies were concluded in time to be presented at the SLAC BAW-2 on January 19, 2011.

GDE Baseline Assessment Workshop (BAW-2)

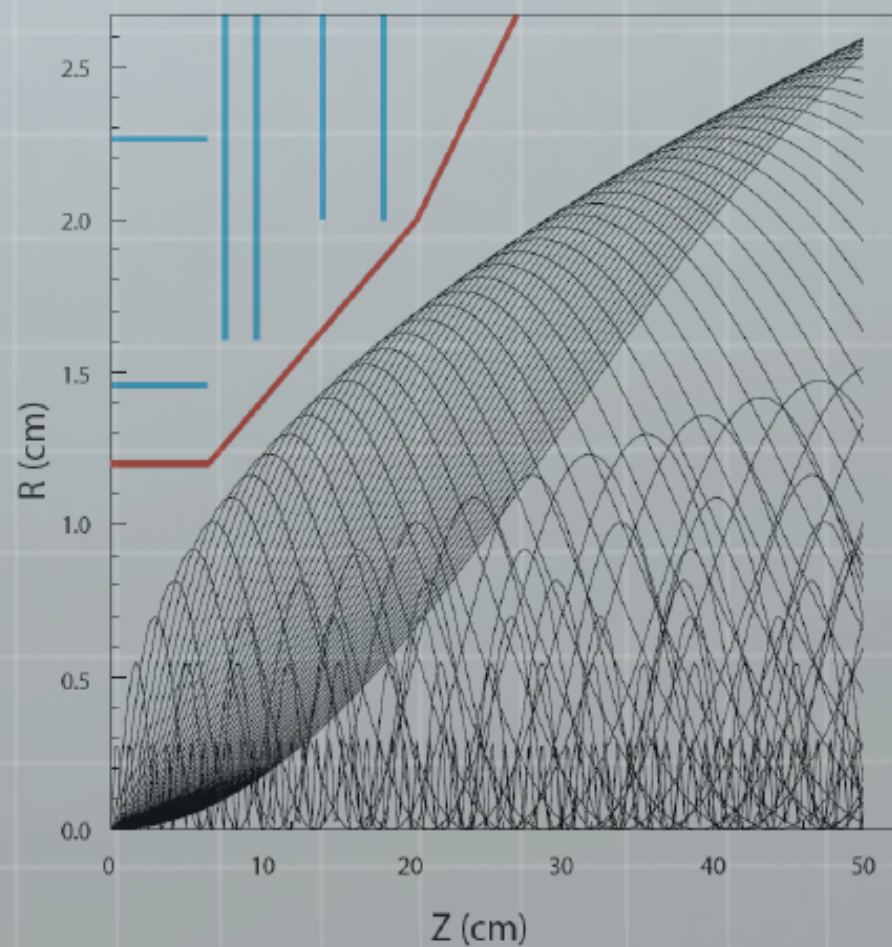
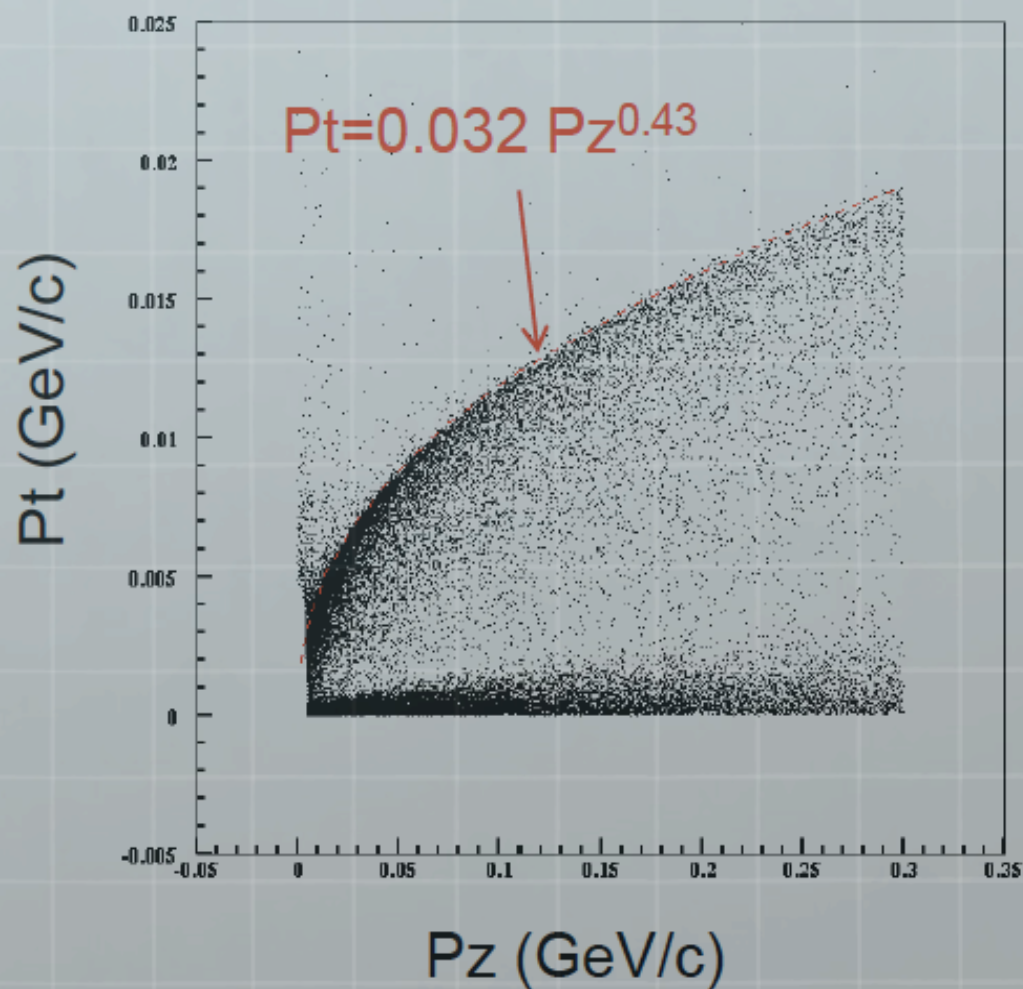
from Tuesday 18 January 2011 at 08:00 to Friday 21 January 2011 at 18:00 (America/Los_Angeles)
at SLAC (ROB (Research Office Building #48))

Wednesday 19 January 2011

- 14:00 **Low-mass susy scenario study** 25'
Speaker: Paul Grannis (Stony Brook University)
Material: [Slides](#) 
- 14:25 **Higgs cross section and mass measurement** 25'
Speaker: Hengne Li (LPSC)
Material: [Slides](#) 
- 14:50 **Higgs branching ratios study** 20'
Speaker: Hiroaki Ono (Nippon Dental University)
Material: [Slides](#) 
- 15:10 **Background studies** 20'
Speaker: Takashi Maruyama (SLAC)
Material: [Slides](#)  
- 15:30 **break-->** 30'
- 16:00 **physics requirements for positron polarization** 25'
Speaker: Sabine Riemann (DESY)
Material: [Slides](#)  
- 16:25 **physics studies with polarization** 25'
Speaker: Mikael Berggren (DESY Hamburg)
Material: [Slides](#) 

Pair Edge and Beampipe Design

SB2009 500 GeV TF



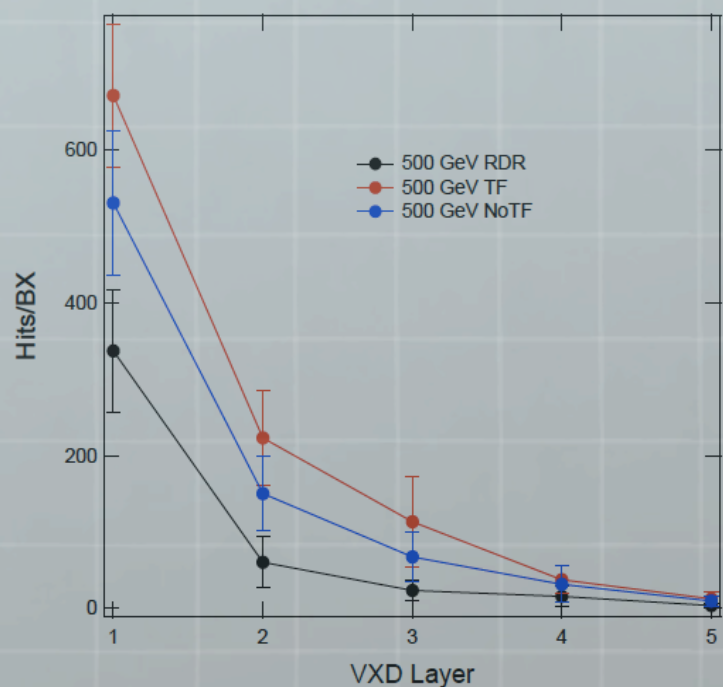
T. Maruyama, BAW-2

Machine Backgrounds

VXD hits

BeamCal Energy

• e⁺/e⁻ hits at 500 GeV



	250GeV TF	250GeV NoTF	350GeV TF	350GeV NoTF	500GeV RDR	500GeV TF	500GeV NoTF	1000GeV V TF	1000GeV V NoTF
NO-DID Energy (TeV)	12.9	9.8	20.5	15.5	20.9	58.8	45.3	49.4	43.5
Anti-DID Energy (TeV)	6.5	4.8	11.1	8.3	12.0	38.2	29.1	32.0	28.8
Anti-DID radiation (Mrad/year)					100	160	120		

500 GeV TF has x3 more energy/BX than RDR

- More difficult to tag high energy e⁻.
- SUSY search sensitivity is reduced.

Increased, but tolerable for most technologies considered for ILC

T. Maruyama, BAW-2

Machine Backgrounds

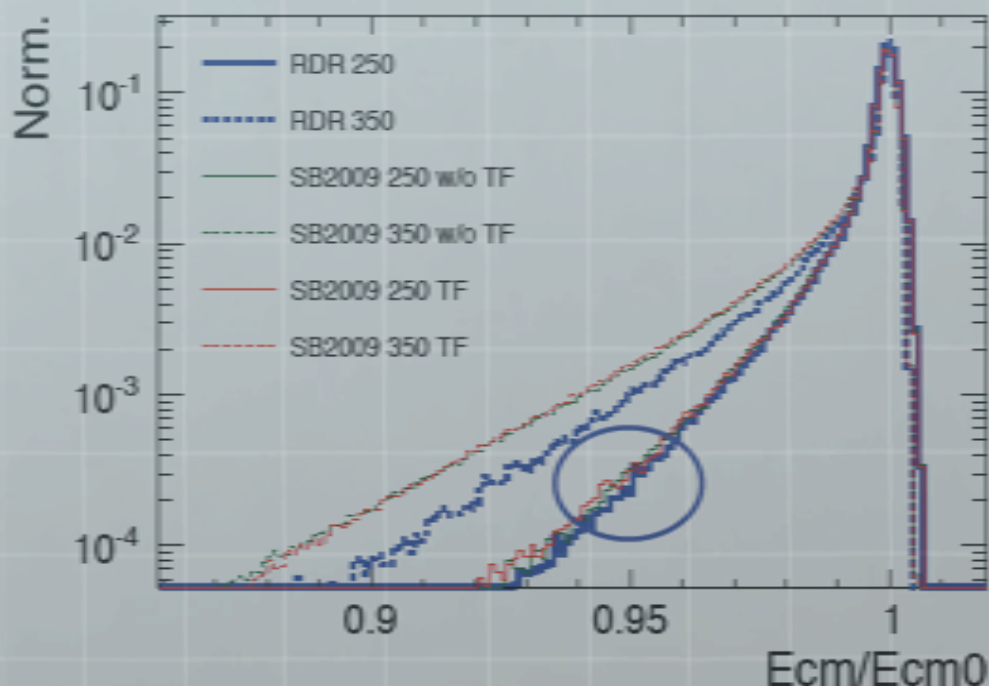
CONCLUSIONS (T. Maruyama)

- The beam pipe design in both SiD and ILD is compatible with the SB2009 beam parameters.
 - The pair edge does not depend on the beam focus scheme (TF vs. NoTF).
- There are x2 more VXD hits in 500 GeV TF but the detector tolerance is dependent on the pixel size and readout time.
- x3 more energy per bunch crossing in the BeamCal.

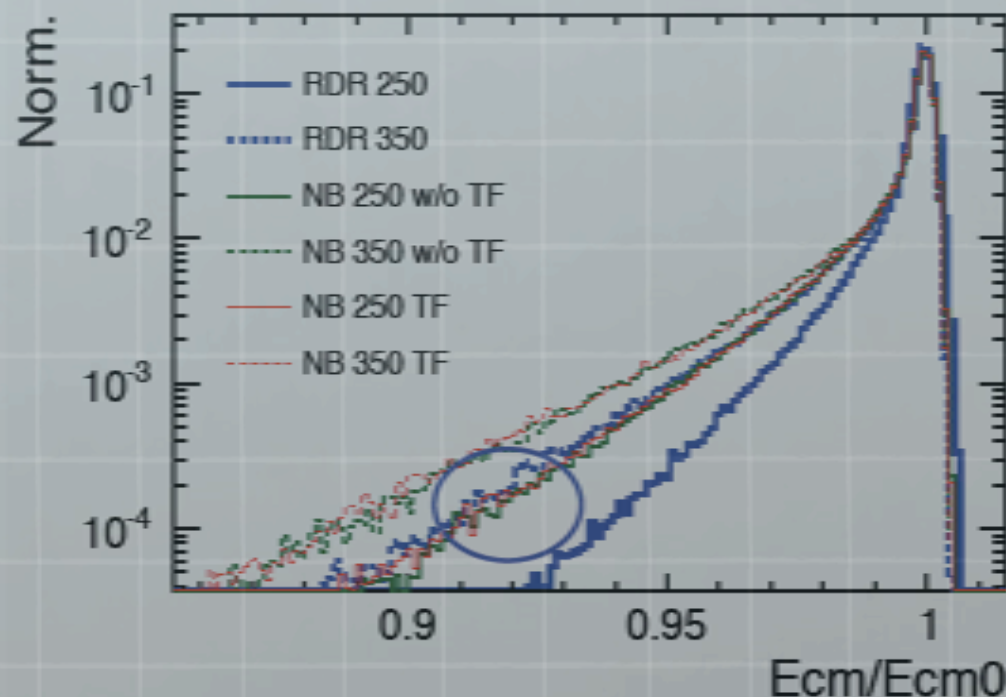
Higgs Physics

Differential Luminosity Spectra

RDR vs. SB2009



RDR vs. New Baseline (NB)

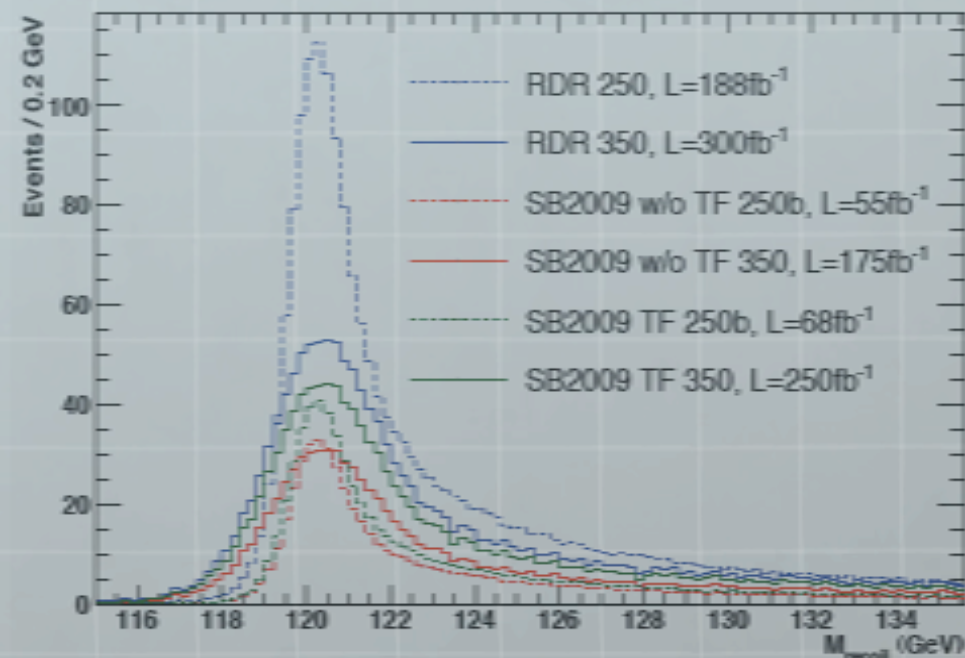


While the New Baseline has more beamstrahlung, it supplies significantly more integrated luminosity at low energy, a beneficial trade-off for Higgs Physics.

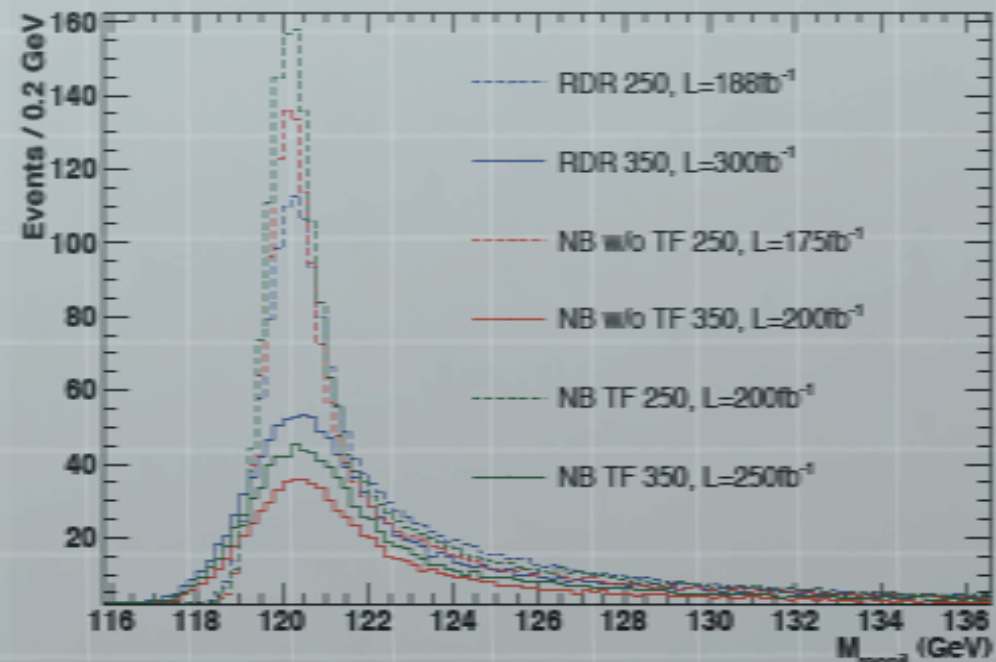
Higgs Recoil Mass Spectra after Fast Simulation

Integrated Luminosity of a 4-years data taken

RDR vs. SB2009



RDR vs. New Baseline



Comparison shows:

- 250 GeV center of mass energy gives narrower peak than 350 GeV: momentum resolution
- Luminosity is a key factor impacts this analysis.
- NB @ 250 GeV, peak is narrower compared to RDR @ 250 GeV:

Smaller beam energy spread: RDR250 (e^- 0.28%, e^+ 0.18%) vs. NB250 (e^- 0.22%, e^+ 0.14%)

ZH- $\rightarrow\mu\mu$ X channel

Polarization: e^- : -80% e^+ : +30%

Beam Par	\mathcal{L}_{int} (fb $^{-1}$)	ϵ	S/B	M_H (GeV)	σ (fb) ($\delta\sigma/\sigma$)
RDR 250	188	55%	62%	120.001 \pm 0.043	11.63 \pm 0.45 (3.9%)
RDR 350	300	51%	92%	120.010 \pm 0.087	7.13 \pm 0.28 (4.0%)
SB2009 w/o TF 250	55	55%	62%	120.001 \pm 0.079	11.63 \pm 0.83 (7.2%)
SB2009 w/o TF 350	175	51%	92%	120.010 \pm 0.110	7.13 \pm 0.37 (5.2%)
SB2009 w/TF 250	68	55%	62%	120.001 \pm 0.071	11.63 \pm 0.75 (6.4%)
SB2009 w/TF 350	250	51%	92%	120.010 \pm 0.092	7.13 \pm 0.31 (4.3%)
NB w/o TF 250	175	61%	62%	120.002 \pm 0.032	11.67 \pm 0.42 (3.6%)
NB w/o TF 350	200	52%	84%	120.003 \pm 0.106	7.09 \pm 0.35 (4.9%)
NB w/TF 250	200	63%	59%	120.002 \pm 0.029	11.68 \pm 0.40 (3.4%)
NB w/TF 350	250	51%	89%	120.005 \pm 0.093	7.09 \pm 0.31 (4.4%)

Comparison:

- New Baseline design @ 250 GeV gives the best results: better than the RDR design
- Importance at the low energy: Even with 4 times smaller luminosity (68fb $^{-1}$ /250fb $^{-1}$), SB2009 @ 250 GeV can still give better result on the Higgs mass measurement than SB2009 @ 350GeV.
- 350 GeV center of mass energy gives better signal over background (S/B)

Higgs Branching Ratios

- Obtain slightly better BR measurement Accuracy at 350 GeV
 - ~25% improvement from 250 GeV with same $L=250 \text{ fb}^{-1}$
 - ~25% degradation with $L=188 \text{ fb}^{-1}$ (RDR250 parameter) as same fraction as peak luminosity reduction
- Better selection efficiency at 350 GeV because of better mass resolution and signal separation from background

	E_{cm}	$\Delta\text{BR(cc)}/\text{BR(bb)}$
Neutrino ($\nu\nu\text{H}$)	250	20.7%(28.9%)
	350	14.2%
Hadron ($qq\text{H}$)	250	23.0%(31.3%)
	350	16.4%
Muon ($\mu\mu\text{H}$)	250	39.5%(45.3%)
	350	43.9%
Electron ($ee\text{H}$)	250	47.5%(50.9%)
	350	37.8%
Combined	250	13.7%(18.0%)
	350	10.0%

Preliminary results
 (): $L=188\text{fb}^{-1}$ scaled as RDR250
 Statistical error only ¹⁷

Low mass SUSY (an example)

	M	Final state	(BR(%))			
\tilde{e}_R	143	$\tilde{\chi}_1^0 e$ (100)				
\tilde{e}_L	202	$\tilde{\chi}_1^0 e$ (45)	$\tilde{\chi}_1^\pm \nu_e$ (34)	$\tilde{\chi}_2^0 e$ (20)		
$\tilde{\mu}_R$	143	$\tilde{\chi}_1^0 \mu$ (100)				
$\tilde{\mu}_L$	202	$\tilde{\chi}_1^0 \mu$ (45)	$\tilde{\chi}_1^\pm \nu_\mu$ (34)	$\tilde{\chi}_2^0 \mu$ (20)		
$\tilde{\tau}_1$	135	$\tilde{\chi}_1^0 \tau$ (100)				
$\tilde{\tau}_2$	206	$\tilde{\chi}_1^0 \tau$ (49)	$\tilde{\chi}_1^\pm \nu_\tau$ (32)	$\tilde{\chi}_2^0 \tau$ (19)		
$\tilde{\nu}_e$	186	$\tilde{\chi}_1^0 \nu_e$ (85)	$\tilde{\chi}_1^\pm e^\mp$ (11)	$\tilde{\chi}_2^0 \nu_e$ (4)		
$\tilde{\nu}_\mu$	186	$\tilde{\chi}_1^0 \nu_\mu$ (85)	$\tilde{\chi}_1^\pm \mu^\mp$ (11)	$\tilde{\chi}_2^0 \nu_\mu$ (4)		
$\tilde{\nu}_\tau$	185	$\tilde{\chi}_1^0 \nu_\tau$ (86)	$\tilde{\chi}_1^\pm \tau^\mp$ (10)	$\tilde{\chi}_2^0 \nu_\tau$ (4)		
$\tilde{\chi}_1^0$	96	stable				
$\tilde{\chi}_2^0$	175	$\tilde{\tau}_1 \tau$ (83)	$\tilde{e}_R e$ (8)	$\tilde{\mu}_R \mu$ (8)		
$\tilde{\chi}_3^0$	343	$\tilde{\chi}_1^\pm W^\mp$ (59)	$\tilde{\chi}_2^0 Z$ (21)	$\tilde{\chi}_1^0 Z$ (12)	$\tilde{\chi}_1^0 h$ (2)	
$\tilde{\chi}_4^0$	364	$\tilde{\chi}_1^\pm W^\mp$ (52)	$\tilde{\nu} \nu$ (17)	$\tilde{\tau}_2 \tau$ (3)	$\tilde{\chi}_{1,2} Z$ (4)	$\tilde{\ell}_R \ell$ (6)
$\tilde{\chi}_1^\pm$	175	$\tilde{\tau}_1 \tau$ (97)	$\tilde{\chi}_1^0 q \bar{q}$ (2)	$\tilde{\chi}_1^0 \ell \nu$ (1.2)		
$\tilde{\chi}_2^\pm$	364	$\tilde{\chi}_2^0 W$ (29)	$\tilde{\chi}_1^\pm Z$ (24)	$\tilde{\ell} \nu_\ell$ (18)	$\tilde{\chi}_1^\pm h$ (15)	$\tilde{\nu}_\ell \ell$ (8)

Slepton and
gaugino masses
in SM2 scenario

Luminosity vs. Energy

Ecm /	200	250	350	500
Ecm scaling	0.80	1.00	1.40	2.00
RDR		0.75	1.20	2.00
NB TF totL	0.50	0.80	1.00	2.00
NB TF pkL	0.50	0.71	0.77	1.44
NB noTF totL	0.50	0.70	0.80	1.50
NB noTF pkL	0.50	0.67	0.70	1.10

\mathcal{L} vs E for different parameter sets ($10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)

Low Mass SUSY Run Strategy

Beams	Energy	Pol.	\mathcal{L}^*	\mathcal{L}	comments
$e^+ e^-$	500	L/R	335	335	top energy for end point measurements
$e^+ e^-$	M_Z	L/R	10	45	calibrate with Z's (4 times)
$e^+ e^-$	270	L/R	100	185	scan $\chi_1^0 \chi_2^0$ and stau1 pair thresholds
$e^+ e^-$	285	R	50	85	scan smuonR pair threshold
$e^+ e^-$	350	L/R	40	60	scan ttbar, selectronR-selectronL and $\chi_1^+ \chi_1^-$ thresholds
$e^+ e^-$	410	L	60	75	scan stau2 pair and smuonL pair thresholds
$e^+ e^-$	580	L/R	90	120	sit above $\chi_1^+ \chi_2^-$ threshold for χ_2^+ mass
$e^- e^-$	285	RR	10	95	scan with $e^- e^-$ for selectronR mass

P. Grannis, BAW-2

Low Mass SUSY (SM₂)

Precisions

sparticle	Ecm scale	RDR		NB TF totL		NB TF pkL		NB noTF totL		NB noTF pkL	
	$\delta M(\text{GeV})$	$\delta M(\text{GeV})$	rel to Ecm	$\delta M(\text{GeV})$	rel to Ecm	$\delta M(\text{GeV})$	rel to Ecm	$\delta M(\text{GeV})$	rel to Ecm	$\delta M(\text{GeV})$	rel to Ecm
selectron_R	0.02	0.02	0%	0.02	0%	0.02	0%	0.02	0%	0.02	0%
selectron_L	0.20	0.21	3%	0.21	7%	0.25	25%	0.25	22%	0.28	38%
smuon_R	0.07	0.07	3%	0.07	3%	0.08	20%	0.08	18%	0.09	33%
smuon_L	0.51	0.52	2%	0.53	4%	0.62	21%	0.61	19%	0.70	36%
stau_1	0.64	0.82	29%	0.73	13%	0.78	22%	0.78	22%	0.81	26%
stau_2	1.10	1.25	13%	1.25	13%	1.34	22%	1.35	22%	1.39	26%
sneutrino_e	~1	~1		~1		~1		~1		~1	
sneutrino_mu	~7	~7		~7		~7		~7		~7	
sneutrino_tau	--	--		--		--		--		--	
chi1^0	0.07	0.07	0%	0.07	0%	0.08	18%	0.08	15%	0.09	35%
chi2^0	0.12	0.14	13%	0.14	13%	0.15	22%	0.15	22%	0.15	26%
chi3^0	8.50	8.50	0%	8.50	0%	10.02	18%	9.81	15%	11.49	35%
chi4^0	--	--		--		--		--		--	
chi1^+	0.18	0.19	8%	0.21	18%	0.24	35%	0.24	32%	0.25	41%
chi2^+	4.00	4.00	0%	4.00	0%	4.71	18%	4.62	15%	5.41	35%

Comments:

- ❖ The mass precisions with the RDR parameter set degrade only a few % relative to E_{cm} scaling (we did not consider the effect of the beamstrahlung for either the E_{cm} scaling or RDR cases).
- ❖ For the NB parameters with travelling focus, mass precisions degrade by $\sim 20\%$ relative to E_{cm} scaling (considering only \mathcal{L} within 1% of nominal E).
- ❖ For NB parameters with no travelling focus, mass precisions degrade by $\sim 35\%$ relative to E_{cm} scaling (\mathcal{L} within 1% of E_{nom}).
- ❖ For the NB parameters, mass precisions using only the luminosity delivered within 1% of nominal energy are degraded by $\sim 15\%$ from those calculated using the total delivered luminosity.
- ❖ In the spirit of these rough estimates, the run time for equal mass precision scales as $(\mathcal{L}/\mathcal{L}_{E_{cm} \text{ scaling}})^2$

P. Grannis, BAW-2

Precision physics with polarized beams

- enhancement of SM contributions by $(1-P_{e^-}P_{e^+}) \Leftrightarrow$
enhancement of effective luminosity \Rightarrow

- **Enhancement factors:**

$(\pm 80\%, \pm 60\%) \Leftrightarrow 1.48 \rightarrow \delta_{\text{stat}}$ improved by 22%

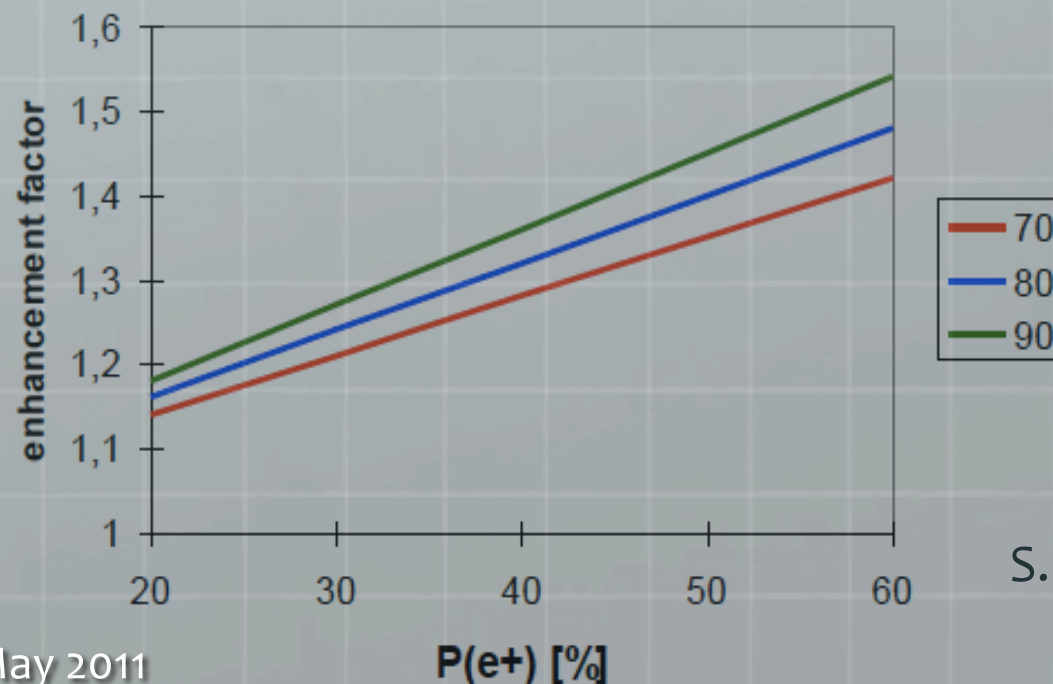
$(\pm 80\%, \pm 34\%) \Leftrightarrow 1.27 \rightarrow \delta_{\text{stat}}$ improved by 13%

$(\pm 80\%, \pm 22\%) \Leftrightarrow 1.18 \rightarrow \delta_{\text{stat}}$ improved by 8%

Could
compensate
reduced
luminosity

- Important for fermion-pair production, Higgs strahlung,
TGC

More examples of
improved physics
reach with P_{e^+} -
M. Berggren, BAW-2



S. Riemann, BAW-2

Positron Polarization

- The physics reach of the machine is significantly enhanced by positron polarization.
- For example, for s-channel production, the equivalent gain in luminosity is 8 % for every 10 % of positron polarization.
- Thus a positron polarization of 30 % is equivalent to an increase of almost 25 % in luminosity.
- For some physics processes the gain is larger.
- We therefore support the efforts to provide the largest polarization which is reasonably achievable and which delivers the highest effective luminosity.

Summary of Study

- 🌐 The large impact at low energy of the SB2009 parameter set was found to have been largely ameliorated, although not eliminated, by the improved low energy luminosity performance.
- 🌐 Running at the Higgs-Z threshold remains a very important goal for model independent Higgs measurements, as well as the unambiguous spin determination. Top threshold running, with minimal energy spread, is also a priority.


Summary (2)

- The high energy (0.5 TeV) performance reaches the ILCSC scope document requirements under the assumption of a working traveling focus. Without the traveling focus the high energy luminosity degrades by 25%, which does negatively impact physics
- Footnote on proposed “new low charge” alternative expressed to GDE following BAW-2
 - The proposal of a “new low charge” alternative ILC design presented at BAW-2 was interesting. If the low charge option is pursued by the GDE, the physics and detector groups would be interested in assessing the impact of these parameters on ILC physics and, in particular, the experimental backgrounds.

1 TeV

- The parameters for 1 TeV are needed by the physics groups to prepare simulations for the Detailed Baseline Document
- The GDE is now working on the TeV upgrade
- It will be helpful when a set of beam parameters for the simulation is established, enabling this work to proceed

Appreciation

-  We would like to thank the GDE machine Working Groups for their intense efforts to address the issues that were raised by these physics analyses